THE USE OF THE COINCIDENCE TECHNIQUE IN THE INVESTIGATION OF ISOMERIC TRANSITIONS

BY

PETER AXEL

B.A., Brooklyn College, 1943
M.S., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICS
IN THE GRADUATE COLLEGE OF THE
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I owe a similar debt to Professor S. M. Dancoff for the work on the classification of isomers. The results presented herein are merely more quantitative data based on a preliminary correlation which he had done.

R. UNIV. BIBLIOTHEEK LEIDEN

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Introduction

The work which is described was done to illustrate the applicability of the coincidence and the delayed coincidence techniques to the investigation of complicated nuclear energy level structures. The versatility of this technique was shown by its application to two essentially different experimental problems. The first of these was an investigation of the radiation emitted immediately after neutron capture in Gadolinium. The second problem involved a study of the decay scheme of the 143 day isomeric state of Te^{121}.

In order to test the reliability of the theory of internal conversion and of the relative probability of energetically possible transitions, the theory was correlated with existent data on internal conversion. The phases of theory which agree with these data were then applied to the interpretation of the results of this experimental study.

The equipment which was designed and used is described.

Summary of Results

It has been known that the nuclear isomers could be classified into groups corresponding to different values of the angular momentum carried off by the photon. However, the classification had not been presented in any form which permitted a simple comparison with theory. The present correlation consists of relating the lifetime for gamma ray emission with the energy of the gamma ray. The experimentally determined lifetimes are converted to gamma ray lifetimes by correcting for internal conversion. The resultant data are then compared with the semi-classical electrodynamic formula:

$$\tau_\gamma = (3(l!)^2/\rho^{2l})\ (137/W)^{2l+1}\ (h/2\pi mc^2)$$

If allowance is made for the variations which can be expected from nuclear matrix elements, the general grouping of the isomers is shown to substantiate the broad outlines of the theory. It is also shown that this grouping is sometimes different from that which is arrived at by considering the ratio of K conversion to L conversion. In the known cases, the discrepancies can be explained by magnetic conversion. However, insufficient experimental data are available on this ratio and on the absolute conversion coefficients to adequately test this point.

A summary of this material is available in the Physical Review, Volume 76, Pages 892-897, October 1st, 1949.

The experiments which were performed were chosen in an attempt to add to the data which can be used for testing the theory. Coincidence techniques were used to obtain quantitative data concerning branching ratios and decay schemes. Delayed coincidence techniques and a specially designed oscilloscope were used to measure short half lives.

One interesting type of experiment which can add significant data is that of observing the radiation given off at the time of neutron capture. Since it might be expected that a complicated gamma ray spectrum would be observed, techniques were used which allowed a partial analysis of the data.

Neutron capture was investigated in Gadolinium. Gadolinium was chosen because of its large capture cross section and the known existence of a group of soft electrons. The existence of these electrons allowed a partial isolation of the gamma rays. The electron energy was measured and found to be about 100 Kev. An upper limit of 10^{-8} seconds was placed on the lifetime of the state which emits this electron. This limit is low enough to eliminate the possibility that the multipole order of the transition is equal to or greater than 3. Although no gamma ray is visible from this transition it is not possible from this experiment to set a lower limit on the internal conversion coefficient which is high enough to represent a contradiction with theory. However, data reported

by Amaldi and Rasetti do indicate a discrepancy.

Analysis of the capture gamma ray data shows evidence for several cascaded gamma rays following neutron capture. Simplifying assumptions give an average of about 3.5 gamma rays per capture. A gamma ray absorption curve shows the presence of gamma rays in the 1 Mev region.

The neutron capture data suffer from a very large background caused by the capture of gamma rays in the paraffin which is used to slow down the neutrons. Because of the existence, elsewhere, of much better slow neutron sources which can be made free from gamma rays, no further neutron capture experiments were performed.

The general coincidence technique was then applied to resolve the contradictions existent in the decay of the 143 day isomeric state of Te^{121}. Coincidences were observed between electrons and gamma rays and between X-rays and gamma rays. A quantitative comparison was then made between the various coincidences. On the basis of these data it is possible to establish some branching ratios. These ratios are then used to construct two possible decay schemes.

VITA

Peter Axel was born in Brooklyn, New York on May 12, 1923. He attended Brooklyn College from September, 1939 to June, 1943, when he received a Bachelor of Arts degree with majors in both Physics and Chemistry.

From July, 1943 until February, 1946, he was a Staff Member at the Radiation Laboratory at Massachusetts Institute of Technology. His duties there consisted of electronic design and development as part of the O.S.R.D. program during World War II. He also contributed several chapters to Volume 22 of the M.I.T. Radiation Laboratory Series, "Cathode Ray Tube Displays".

From February, 1946 until January, 1949, he was a student at the Graduate College of the University of Illinois. During this time he was continually employed as either a Teaching or Research Assistant in the Department of Physics. In June, 1947 he received the degree of Master of Science in Physics.

He is associated with Sigma Xi, Pi Mu Epsilon, The American Physical Society and The Institute of Radio Engineers.

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